magnetized as weakly as is consistent with the condition that the apparent shall not greatly differ from the true dip, we shall obtain two more equations of the form

$$n'''(A-B)=(\theta''')-\theta,$$
$$n''''(A+B)=(\theta'''')-\theta;$$

and these four equations, when suitably combined, will determine the values of the three unknown quantities A, B, θ.

The magnetic moments involved in these equations may be determined with little trouble, and with sufficient accuracy, by placing the needle as a deflector on a unifilar magnetometer, and observing the angle of deflection produced thereby upon the suspended magnet.

A series of observations has been commenced by the author with the view of testing whether the true dip can be determined exactly with a single needle by the method above described, the results of which he hopes to communicate to the Royal Society hereafter.

The Society then adjourned over the Whitsuntide Recess to Thursday, May 27.

May 27, 1869.

Lieut.-General SABINE, President, in the Chair.

The following communications were read :—

I. "On the Laws and Principles concerned in the Aggregation of Blood-corpuscles both within and without the vessels." By Richard Norris, M.D., Professor of Physiology, Queen's College, Birmingham. Communicated by Dr. Sharpey. Received April 29, 1869.

(Abstract.)

In 1827, or forty-one years ago, the phenomenon which forms the subject of this paper was first observed by Mr. Joseph Jackson Lister and the late Dr. Hodgkin.

To these observers the microscope revealed the fact that if a minute drop of human blood is placed between two plates of glass, the red corpuscles apply themselves to each other by their concave surfaces in such a manner as to form long cylindrical masses, which resemble piles of coin, and that very frequently these piles are so arranged as to form with each other a complete network of rouleaux with clear intervening spaces occupied by liquor sanguinis.

Simple as this observation may appear, its importance in a pathological point of view can scarcely be overrated ; for upon its correct interpretation depends our knowledge of the real nature of one of the most marked characteristics of inflammation, viz. the phenomenon of inflammatory or homogeneous stasis.

During the forty years which have elapsed since the discovery of this

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fact, many theories have been advanced to explain its nature; but all of them, without exception, have laboured under the disadvantage of being purely hypothetical in their character, and quite incapable of demonstration by an appeal to experiment. Thus, while some writers have attributed the effect to an imaginary law of vital attraction, others have more correctly referred it to the operation of some unexplained physical cause.

Professor Lister (son of the original observer already mentioned), who has devoted much attention to this subject, says, in a paper submitted to the Royal Society, June 18, 1857, and published in the Philosophical Transactions for 1858, p. 648:—"For my own part, I am satisfied that the rouleaux are simply the result of the biconcave form of the red disks, together with a certain though not very great degree of *adhesiveness*, which retains them pretty firmly attached together when in the position most favourable for its operation, viz. when the margins of their concave surfaces are applied accurately together, but allows them to slip upon one another when in any other position. *There is never to be seen anything indicating the existence of an attractive force drawing the corpuscles towards each other: they merely stick together when brought into contact by accidental causes.* Their adhesiveness does not affect themselves alone, but other substances also, as may be seen when blood is in motion in an extremely thin film between two plates of glass, when they may be observed sticking for a longer or shorter time to one of the surfaces of the glass, each one dragging behind it a short tail-like process."

Again, at the end of section I., p. 652 of the same paper, Lister says, "From the facts detailed in this section, it appears that the aggregation of the corpuscles of blood removed from the body *depends on their possessing a certain degree of mutual adhesiveness*, which is much greater in the colourless globules than in the red disks, and that in the latter this property, though apparently not dependent upon vitality, is capable of remarkable variations *in consequence of very slight chemical changes in the liquor sanguinis.*"

From these quotations it is apparent that Mr. Lister ignores altogether the idea of the aggregation of the corpuscles being due to an *attractive force or energy*, and refers it to *adhesiveness or stickiness* of the corpuscles; in his own words, "they merely stick together when brought into contact by accidental causes." At the same time he states that this adhesiveness is liable to great variations, both in the way of increase and diminution, by very slight changes in the chemical qualities of the plasma.

Dipping deeper into the writings of Lister, we find that this idea of adhesiveness or stickiness of the corpuscles is retained in his explanation of the nature of inflammatory stasis. And his views upon the subject generally may be summed up in three propositions:—

1. The blood-corpuscles exhibit no tendency to unite together in healthy blood within the vessels, although such blood may be in a state of rest.

2. The corpuscles become suddenly adhesive (in 10 seconds) when, by being shed, the blood is brought into contact with ordinary matter.

3. Irritation, by reducing the vitality of the surrounding tissues, causes them to bear the same relation to the blood within the vessels in their immediate vicinity as ordinary matter does to that which has been shed, inducing adhesiveness of the corpuscles, and thus bringing about inflammatory stasis.

These effects upon the blood-corpuscles are assumed by Lister to depend upon *chemical* changes induced by ordinary matter or by vitally degraded tissues upon the plasma of the blood; but inasmuch as chemical changes cannot occur without corresponding physical modifications, it is quite as rational to refer the increased aggregating-tendency displayed by the corpuscles to physical as to chemical changes in the liquor sanguinis; and this view has the advantage of not requiring us to believe that the functional activity of the tissues is depressed by mild forms of irritation—an idea which is opposed to all we know of the increased nutritive and formative changes which follow in the wake of irritation.

Having now briefly reviewed the existing position of the subject, we will proceed to consider the real causes at work in the production of the phenomenon under consideration.

Many years since, having familiarized myself with the behaviour of, and the appearances presented by blood-corpuscles under almost every conceivable condition, both within and without the vessels, I became profoundly impressed with the conviction that these phenomena had their origin in some physical law of attraction, and at the same time felt not the less certain that, if this view proved to be correct, the behaviour of the blood-corpuscles would be found to be no isolated exhibition of this law, and that, provided conditions similar to those which exist in the case of the blood-corpuscles could be obtained, many illustrative examples of the operation of the law would be immediately forthcoming.

That such attractive force did not exert its influence through distances readily appreciable was obvious, and this fact at once indicated that it must be sought for among those forms of attraction which have been designated molecular.

After much experiment and reflection I came, in 1862, to the conclusion that these phenomena were due to no less universal a law than that of *cohesive attraction*; and I embodied the views I then held upon the subject in a paper which was read before the Royal Society, and published in the Proceedings, entitled "The Causes of various Phenomena of Attraction and Adhesion as exhibited in Solid Bodies, Films, Vesicles, Liquid Globules, and Blood-corpuscles." Since that time other departments of physiology have occupied my attention; and I have only been induced to recur to the old theme because I find that, in some recent references to the history of this subject, my observations have not been mentioned, from which I am led to infer either that my views had not been sufficiently put forward, or that my experiments had failed to produce conviction in others. I therefore now present the result of a renewed investigation, in which I

believe I have established, by conclusive experiments, the correctness of my explanation of the phenomena.

Among the various modes of aggregation which the blood-corpuscles undergo, two typical forms stand prominently forward, of which all others are merely modifications. The one appears to be dependent upon the normal disk-shape, the other upon the globular or spherical form which the corpuscles assume on the addition of various substances to the blood, such as gum, gelatine, linseed mucilage, potash, &c.

With the first of these modes of aggregation, viz. into rouleaux, we are all sufficiently familiar; and an excellent notion of the character of the second form may be obtained by a careful examination of microphotographs of the blood-corpuscles which have been obtained instantaneously by exploding magnesium in heated oxygen*.

In order to leave as little as possible to hypothesis, it was desirable as a preliminary step to make sure that these differences in form of the corpuscles were the real cause of the diverse modes of arrangement—whether, in fact, we could safely predicate that disk-shaped bodies having an attraction for each other would arrange themselves so as to form rolls or cylindrical masses, and whether, on the other hand, attracting spheres of soft material would attach themselves together in such a fashion as to cause plane surfaces to be opposed to each other—in a word, to convert themselves by mutual attraction into polyhedral bodies just as they might do under mutual compression.

In the first place, we had to ascertain experimentally how disk-shaped bodies, having the utmost freedom of movement, and possessing an attraction for each other, would arrange themselves.

In casting about for the conditions to make such an experiment, I remembered a very familiar phenomenon which had often excited my curiosity, viz. the rapidity with which a bubble or a small floating fragment upon the surface of a cup of tea or other liquid rushes to the side of the containing vessel, or with which two such bubbles or fragments rush together, the moment they approach within a certain range. I determined to see if I could not make use of this attraction, the true nature of which I at the time imperfectly understood, and with this object prepared a number of circular disks of cork, which I accurately poised so that they should assume and maintain the vertical position when partially immersed in liquid. On throwing these disks into liquid, I had the satisfaction of seeing them run together and form themselves into the most perfect rouleaux after the fashion of the blood-disks.

This experiment has the value of demonstrating that if the blood-disks attracted each other, *their shape* would determine the formation of rouleaux.

As regards the behaviour of spherical vesicles or globules which attract

* Specimens of these, as well as the several experiments referred to in the paper, were exhibited to the Society.

each other, it is found that the moment any point in their convex surfaces is made to touch, these surfaces become flattened, and consequently bubbles in a group convert each other into polyhedral-shaped bodies. This effect is not due to compression, but to a *progressive mutual attraction* of the surfaces of these bodies for each other.

As soap-bubbles are vesicles with aërial contents, and are therefore physically unlike the blood-corpuscles, it became desirable to ascertain how vesicles with liquid contents would behave in regard to each other. This was accomplished by placing in a large test-tube a solution of soap, and upon its surface a stratum of petroleum an inch or so in depth ; the petroleum does not mix with or injure the soap solution, which is the case with most other substances. A glass tube is now passed through the petroleum into the solution of soap below. On blowing down the tube, we succeed in forming innumerable small bodies or corpuscles of a spherical form, which are very plastic, and the contents of which consist of petroleum, and the external envelope or vesicle of soap. Corpuscles so produced float in the upper stratum of petroleum, and are found to unite themselves into groups and masses in precisely the manner of the air-bubbles, although they are entirely submerged in liquid.

These experiments show that disk-shaped bodies, having an attraction for each other, will arrange themselves in rolls or cylindrical masses, and that spherical bodies of a plastic character and vesicular structure, be their contents aërial or liquid, will attach themselves together in such a fashion as to cause plane surfaces to be opposed to each other—in a word, convert themselves by a progressive attraction, which commences at their points of mutual contact, into groups of polyhedral bodies.

The question now remaining is, do the blood-corpuscles possess such attractions for each other as those displayed by the objects with which we have been dealing? The reply is that their physical nature being analogous, if the same conditions exist, they cannot escape the influence of the same law. An examination of the photographs and of the drawings of blood-corpuscles exhibited will serve to show that these bodies are amenable to the law which is concerned in grouping together the bubbles and liquid vesicles.

But in the cases we have heretofore been considering, the disks, bubbles, and other factitious objects are not in precisely the same conditions as the blood-corpuscles—the former being only partially, or not at all submerged in liquid, while the latter are entirely so, and nevertheless they run together into rouleaux and groups. It may fairly be asked if the artificial bodies will do the same. The answer obtained by experiment is, that the moment these disks or bubbles are entirely submerged, they lose at once their attraction for each other and fall apart.

For several years I unceasingly asked myself the cause of this difference in behaviour. I at length found that when small bodies, such as disks of cork or gelatine, are first wetted with water, and then submerged in a liquid with

which water will not mix, such as oil of turpentine or petroleum, they will run together in piles or rouleaux, very much in the same way as the blood-disks.

To understand this result, a few simple primary principles must be called to mind. In the first place, the particles which compose any liquid have a mutual attraction for each other; but between the particles which compose different liquids a mutual repulsion may exist, *e.g.* water and oil, or chloroform and water. It is likewise true that there is a mutual attraction between certain liquid and rigid bodies, and also a mutual repulsion between others. Any rigid body which can be wetted by a liquid is regarded as having a cohesive attraction for it, while one which cannot be wetted is said to have no such attraction, or to exert a repulsive influence, as the case may be.

These phenomena therefore depend upon what might be justly termed *double cohesion*—cohesion in the first place between the rigid body and the liquid, and in the second place between the particles of the liquid itself.

If, now, we examine into the cases in which we have complete submergence, viz. the blood-rolls, the gelatine disks, and the loaded cork disks, we find the same law to be in operation. These bodies must all be regarded as localizers of liquids, either by their cohesive attraction for liquids, or, as in the case of the blood-corpuscles, by being receptacles containing liquids.

If the cork disks, bubbles, or other bodies are entirely submerged in water, all attraction ceases, and this because a cohesive equilibrium is established; there is no longer any differentiation such as exists between water and air. If, however, after having wetted these bodies in water, we completely submerge them in a liquid which has a cohesive antagonism to water, or even a liquid which has simply no cohesion for water, which may be known by the insolubility and immiscibility of one liquid in the other, such as turpentine or petroleum, we get the phenomena of attraction precisely as in the atmosphere. This fact is illustrated by taking the cork disks from the water in which they are non-adherent, and placing them in the vessel of petroleum, in which they become instantly attractive of each other.

This principle is further illustrated by the gelatine disks, which are first made to absorb as much water as possible, and are then submerged in petroleum.

In all these cases there are present, therefore, two dissimilar or antagonistic liquids; and upon the presence of these the phenomena depend.

My idea of the blood-corpuscle is that its contents are something essentially different, so far as cohesive attraction is concerned, from the liquor sanguinis—that is to say, not readily miscible with liquor sanguinis. This is of course self-evident, if, according to some modern views, we regard the corpuscles "as tiny lumps of a uniformly viscous matter," inasmuch as such matter must be insoluble in and immiscible with the liquor sanguinis.

The explanation is equally easy if we accept the old and, I believe, the true view, of the vesicular character of these bodies, as we have only to assume that the envelope is so saturated with the corpuscular contents as practically to act as such contents would themselves act, *i. e.* to exhibit a greater cohesive attraction for their own particles than for those of the contiguous liquid.

The cohesive power of the blood-corpuscles varies with varying conditions of the liquor sanguinis; and this is doubtless due to the law of osmosis; for we can readily imagine that when the exosmotic tendency is in excess, the corpuscles will become more adhesive, and, on the contrary, when the endosmotic current prevails, less so. In any case the increased cohesiveness will be due to the increased extrusion of the corpuscular contents upon the surface.

All, then, that is required in the case of the blood-corpuscles, is a difference between their liquid contents and the plasma in which they are submerged. That this difference is not so great as between the liquids used in these experiments is probable; but it must also be remembered that the attraction is not so powerful. The power required to attach the blood-corpuscles together is, on account of their exceeding minuteness, extremely small, as they are thus so much more removed from the influence of gravitation, and brought under that of molecular attraction.

I shall conclude this paper by a brief reference to inflammatory stasis. In one of my papers (communicated to the Royal Society in 1862) I described no less than four distinct forms of stasis. I proposed to designate that induced by irritation homogeneous stasis, because the blood-corpuscles become so blended together as to entirely lose their outlines and present the appearance of a uniform and continuous plug filling up the capillaries.

This peculiar blending of the corpuscles is dependent upon the law I have been describing, viz. that of double cohesion, and is brought about by diminished quantity of liquor sanguinis in a part in proportion to the corpuscles, and by loss of fluidity in that which remains.

One of the primary effects of irritation is neural paralysis of the minute arteries which supply capillary tracts; and this paralysis gives rise to increased diosmotic action, in fact to exudation of liquor sanguinis; consequently there is a lagging behind of the corpuscles, and an increase of their numbers in the capillaries; the plasma, too, which still surrounds the corpuscles in the capillaries, is modified; and when a certain relation has been reached between the corpuscles and the plasma, the former blend together precisely in the same manner as the soap-bubbles, or as the blood-corpuscles exhibited in the photographs. This completely arrests the passage of blood through the capillaries, which become as much occluded as if blocked up by solid fibrin.

I have frequently had opportunities of watching in the transparent webs of frogs the mode in which this homogeneous stasis is resolved. In these creatures the restoration of the circulation commences some hours after the

application of the irritant. When the circulation is about to be resumed, the stagnating mass in the vessel appears to thaw as it were. The corpuscles are not pushed onwards in mass as a coherent plug; but the homogeneity of appearance is suddenly lost by the resumption of their normal form by the corpuscles and the reappearance of their differentiating outlines, which were previously obscured by their blending with one another and with the walls of the vessels. Before this takes place, the vessel very gradually assumes a lighter tint, passing in some instances from a deep red to a pale orange. This appears to be due to a washing away of extruded colouring-matter.

When this change from homogeneity to heterogeneity commences, although sufficiently progressive in its character as it traverses the vessel, it nevertheless takes place with considerable rapidity. It is evidently brought about by the gradual permeation of new liquor sanguinis among the corpuscles, and the contemporaneous abolition of their cohesive attraction for each other in accordance with the principles previously established.

II. "Researches on Turacine, an Animal Pigment containing Copper." By A. W. Church, M.A. Oxon., Professor of Chemistry in the Royal Agricultural College, Cirencester. Communicated by Dr. W. A. Miller, Treas. R.S. Received May 4, 1869.

(Abstract.)

From four species of *Touraco*, or Plantain-eater, the author has extracted a remarkable red pigment. It occurs in about fifteen of the primary and secondary pinion feathers of the birds in question, and may be extracted by a dilute alkaline solution, and reprecipitated without change by an acid. It is distinguished from all other natural pigments yet isolated, by the presence of 5·9 per cent. of copper, which cannot be removed without the destruction of the colouring-matter itself. The author proposes the name *turacine* for this pigment. The spectrum of turacine shows two black absorption-bands, similar to those of scarlet cruorine; turacine, however, differs from cruorine in many particulars. It exhibits great constancy of composition, even when derived from different genera and species of Plantain-eater; as, for example, the *Musophaga violacea*, the *Corythaix albo-cristata*, and the *C. porphyreolopha*.

III. "On the Radiation of Heat from the Moon." By the Earl of Rosse, F.R.S. Received May 27, 1869.

The following experiments on Lunar Radiant Heat were undertaken with the view of ascertaining whether with more powerful and more suitable means than those previously employed by others, with little or no success, it would be possible to detect and estimate the amount of heat which reaches the earth's surface from the moon.